are accepted only after considerable negotiation and considerable modification of the manuscript, hardly exist in Russia.

The minimum time of almost two months required for us to place an accepted manuscript in the reader's hands, is set by editorial time requirements, United States Post Office transfer times, delays in the response of the referees and our own manuscript preparations and printing times. These times can be reduced substantially only by increasing our costs—and our page charges—significantly and we choose not to do so. We will then have to bow to our Soviet colleagues' superiority in handling such manuscripts.

The difference in the second groups is more interesting. Our nominal acceptance criteria and mechanisms for establishing those criteria seem to be almost identical to the *JETP* procedures which Azbel describes but it is possible that the compromises required between speed of publication and excellence of presentation are made differently by *PRL* and *JETP*. Indeed we do not believe that fast publication of all papers is really consistent with the excellence of substance and style we attempt to attain for what Azbel so kindly describes as the "most prestigious physical journal."

Are there other differences? We think that a clue to such a difference may lie in Azbel's statement concerning the reception of criticism by *JETP* referees; "Naturally, such a criticism is practically always accepted by the author." For *PRL*, our experience has been almost the opposite; with little hyberbole, we can say that our authors practically *never* accept the criticism of the referee. Why that difference? Are Russian referees more precise and more (or less) responsible? Are Russian authors more acquiescent? Are the editors of *JETP* firmer in their rejections than we are (or can be)?

We do not know the answers to these questions but we suspect that the main cause of the different time lags for the two publications lies in appreciable differences between the expectations of authors, referees and readers of these two, nominally similar, journals.

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10/24/78 *Physical Review Letters*

More on proliferation

Your April article on "Nuclear power and nuclear-weapons proliferation" by Ernest Moniz and Thomas Neff (page 42) ignores fundamental deficiencies in US Government antiproliferation policy:

- Overuse of unilateral approaches
- Failure to make sacrifices in military programs
- Overemphasis of the hypothetical role of deverted reactor-grade plutonium
- Inadequate recognition of underlying energy and economic pressures
- Decisions based on misunderstood technology

Recently J. S. Nye, who was chairman of the Group on Nonproliferation within the National Security Council, wrote an article, "Nonproliferation: A Long-term Strategy,"[1] that contained only one paragraph and a few sentences (out of 22 pages) addressing the influence of the nuclear arms race upon horizontal proliferation. It should also be noted that the Non-Proliferation Act of 1978 fails entirely to relieve proliferation pressure attributable to military nuclear-weapons programs. None of these US Government positions calls for cessation of nuclear-weapons testing, no-first-use of nuclear weapons, or the establishment of nuclear-weapons-free zones.

As long as the weapon-states are unable to reach accord, the primary driving force behind horizontal proliferation (to more nations) will be the continued vertical proliferation (arms-race).

Besides avoiding these proliferation factors above, the evaluation by Moniz and Neff does not take into account possible theft or clandestine transfer of completed weapons or fissile material from nuclear-weapons states as a result of ongoing military production; nor do they give adequate weight to capabilities of nations to build secret installations.

The authors have been misinformed about the inherent degree of resistance afforded by a denatured thorium cycle. It is often stated that, by diluting U^{233} fissile feed with U^{238}, plutonium production will be "substantially reduced" compared to a uranium-cycle reactor. Because of unshielding of the resonances in U^{238}, only a factor of three reduction is likely; this could still allow, in theory, about 14 low-quality weapons to be made per year from the plutonium of a 1 GWe denatured thorium reactor. In addition, the large isotopic difference with U^{238} makes U^{233} relatively easy to separate in a few centrifuge stages. What has also been overlooked is that Th^{232} nuclei that capture neutrons dwell as Pa^{233}, with half-life of about one month, before decaying to U^{233}. Thus, by *chemical* means the Pa^{233} can be separated from the fuel before it is isotopically denatured by the U^{238}; this will produce enough U^{233} to make about 10 weapons-grade critical masses per GWe yr.

It should be kept in mind that U^{233} has better weapons potential than either U^{235} or plutonium, critical mass much less than U^{235}, higher and more dependable explosive-yield than any reactor-grade of plutonium, and is adaptable to either implosion or gun-barrel fission-explosive design because of the absence of inherent spontaneous neutrons that characterize plutonium.

Because several weeks to a month must transpire before enough U^{233} can be milked from Pa^{233}, it can be said that denatured thorium-cycle reactors are more secure against certain forms of diversion than once-through U-cycle reactors. However, in terms of ultimate production of weapons-grade material, a thorium-cycle would be attractive to a government that is hedging for a long-term supply of fissile material to be used to make weapons.

The preceding remarks are often misunderstood to suggest that fissile materials can be easily siphoned from any nuclear fuel cycle. Because of high radiation fields, full-scope safeguards, and an interwoven net of institutional and technological measures, there is a high degree of inherent security associated with the commercial fuel cycle. All irradiated fuel has considerable self-protection against diversion; appropriate collocation, coprocessing and safeguards can provide physical security for the remainder of the fuel cycle.

Another item of technical misinformation repeated by Moniz and Neff is the idea that uranium "... can be isotopically denatured, [plutonium] can not." The situation is far more complicated. Plutonium containing a large fraction of even isotopes has a critical mass at least an order of magnitude larger than pure Pu^{239}. Although it is impossible for an explosion to occur, the yield/weight ratio for isotopically-denatured plutonium can be many orders of magnitude less than for weapons-grade materials. In particular, the spontaneous neutron rates, the heat production, and the radiation effects of Pu^{236}, Pu^{238}, Pu^{240} and Pu^{242} are such that "complicating weapons design" is a serious understatement when attempting to describe the impact of retaining the even isotopes.[3]

Elsewhere,[2] a means of producing isotopically denatured plutonium has been reported. It can be done in any type of reactor, as long as recycled plutonium is segregated from U^{238} during irradiation.

Calculations indicate that in five or ten years enough plutonium denaturant can be produced to prespike reactors intended for export to sensitive nonnuclear-weapons states. These are the countries where the maximum antiproliferation measures must be applied.

Thus, without going into details, there is another role for plutonium recycle: namely to produce isotopically denatured plutonium, a nuclear fuel component not practical for military or paramilitary (terrorist) weapons.

The competitive, economic, and national-security implications of assured fuel supplies, including fissile plutonium, cannot be overlooked. Inflationary pressures are arising from the huge balance-of-payments deficit due to oil imports. There is growing realization that the true occupational-health, social and environmental costs of coal have not been factored into its market price. Consequently, a sense of urgency may be assigned to the recycle and utilization of plutonium for thermal- and fast-neutron reactors.

Policies that are predicated on the banning of plutonium are counterproductive to the reduction of proliferation risk. Policy goals must be separated from technological preselection; the evaluation of technological measures must be free of artificial constraints.

We cannot afford to ignore the economic consequences of an unresolved energy policy. Nor can we forget the underlying entanglement of military momentum and the arms race; these loom as dominant progenitors of proliferation.

References

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2. F. Olds, "The Tail End of the Fuel Cycle," Power Eng., August 1977, page 23; also, A. De Volpi, "All channels of proliferation must be considered," Power Eng., November 1977, page 32.
3. A. De Volpi, *Plutonium, Proliferation, and Policy: Institutional and Technological Impediments to Proliferation* (to be published by Pergamon Press).

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THE AUTHORS RESPOND: We share Alexander De Volpi's concern about the nuclear arms race and about the difficulty in dealing with the entire spectrum of interconnected proliferation problems. However, our article clearly had a limited scope; namely, explication of the technical basis for nuclear fuel cycle choices and of the varying impacts of these alternatives on proliferation.

Within the nuclear-power context, De Volpi expresses opposition to any delay in plutonium utilization. His argument is based partly on the economic consequences of an unresolved energy plan and on the environmental consequences of a major expansion in coal use. Again, these considerations are beyond the scope of our article. However, De Volpi missed or ignored our central point in this regard: resource and economic considerations do not justify plutonium recycling in the next decade or two. This conclusion appears even more easily justified today than when we wrote our article. Time is available before a commitment to plutonium recycle is necessary for a viable nuclear economy, and this time should be used for exploring various technology choices, including the plutonium breeder, with explicit consideration of potential impact on proliferation.

Based on his confidence in safeguards and in the poor weapons quality of reactor-grade plutonium, De Volpi argues that plutonium fuel cycles have a "high degree of inherent security." He states that our assertion that plutonium cannot be isotopically denatured is a piece of "technical misinformation," yet goes on to say precisely the same thing: the critical mass for any isotopic composition is fairly small. We did state that weapon design is complicated substantially by the presence of even-mass plutonium isotopes. The yield/weight ratio is diminished greatly, but it would be a mistake to assume that all would-be proliferators have the same standards as do American bomb designers. De Volpi asserts further that "full-scope safeguards and an interwoven net of institutional and technological measures" provide the necessary security. This begs the question. The definition and implementation of full-scope safeguards in a manner assuring timely warning of diversion has not been achieved internationally. Lacking consensus on the adequacy of safeguards, one cannot dismiss the potential of nuclear power for contributing to proliferation. In particular, plutonium fuel cycles could lead to the latent proliferation discussed in our article.

De Volpi insists that thorium cycles do not offer potential proliferation benefits, thus supporting his preference for plutonium recycle. We made it clear that the U/Th cycle could not provide a "technical fix" to the proliferation problem but must be considered in the context of feasible institutional arrangements. Clearly, if nations are reprocessing spent U/Th fuel, they could (and likely would) extract the plutonium bred from the U^{238} denaturant. The suggestion that they could separate protactinium is then basically irrelevant. What really matters is whether and how reprocessing occurs; the thorium cycle is advantageous only if operated in a once-through mode (improving ore utilization) or with some form of international fuel-reprocessing arrangement. The advantages over a plutonium recycle approach would be that fresh fuel would be denatured and that decreased plutonium production might make the necessary institutional arrangements somewhat easier to achieve. We used the thorium cycles as illustrations of how technological options and an evolving international political/institutional context must be considered jointly from a proliferation perspective.

We hope the reader finds some merit in the importance of creating and maintaining technical options that fit evolving institutional capabilities and of bringing proliferation concerns explicitly into the process of technology choice. We do not consider this an "artificial constraint."

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